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Version of attached file:

Published Version

Peer-review status of attached file:

Peer-reviewed

Citation for published item:

Carroll, G.R. and Khessina, O.M. (2008) 'Product demography of de novo and de alio firms in the optical disk drive industry, 1983-1999.', Organization science., 19 (1). pp. 25-38.

Further information on publisher's website:

http://dx.doi.org/10.1287/orsc.1070.0301

Publisher's copyright statement:

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Additional information:

A journal of the Institute of Management Sciences.

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Organization Science
Vol. 19, No. 1, January–February 2008, pp. 25–38
ISSN 1047-7039 | EISSN 1526-5455 | 08 | 1901 | 0025
informs®
DOI 10.1287/orsc.1070.0301
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Product Demography of *De Novo* and *De Alio* Firms in the Optical Disk Drive Industry, 1983–1999

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Little theory and research addresses the ways organizational context affects the demography of products. We examine this question here by focusing on an organization's mode of market entry. Specifically, we explore differences between firms entering a market *de novo* (start-up) and those entering *de alio* (diversification from another market). We analyze all products ever shipped in the worldwide optical disk drive (ODD) industry, 1983–1999. We find an almost paradoxical empirical pattern, whereby *de novo* firms typically introduce products with widely agreed upon "better" (that is, universally more appealing) technological characteristics. Yet these products generally stay on the market for a shorter time than those of *de alio* firms, whose products generally display less appealing technological features.

Key words: organizational entry mode; *de novo* and *de alio* organizations; product demography; product exit; product turnover; organizational ecology; optical disk drive industry
History: Published online in *Articles in Advance* December 17, 2007.

Introduction

De novo firms (entrepreneurial start-ups) differ from *de alio* firms (entrants from another industry) in their entry conditions (Bruderl and Schussler 1990, Klepper and Simons 2000), their innovation behavior (Khessina 2003), and their market fates (Carroll et al. 1996, Mitchell 1994). Yet, the precise mechanisms by which entry mode translates into innovation and other organization-level outcomes remain unclear. Instead, analysts often assume that *de novo* and *de alio* firms vary in their initial resource endowments and experiences, and relate these conditions to organizational outcomes such as failure (see Carroll and Khessina 2005).

In this paper, we explore a firm's product demography as one possible set of mechanisms through which entry mode may affect organizational outcomes. Among other things, product demography examines the life histories of products to identify technological variation in product offerings and the rates of product exit from markets.

While several prior empirical studies examine product demography, the focus has been mainly on strategic and economic considerations rather than organizational context. Specifically, this research shows a higher rate of product exit from the market (1) when the product ages and becomes obsolete (Stavins 1995, Greenstein and Wade 1998, Cottrell and Nault 2004, de Figueiredo and Kyle 2006); (2) when the product design rests on older technology (Bayus 1998); (3) when the product is designed narrowly for one or few applications (Cottrell and Nault 2004); and (4) when the product faces intense competition from either other products in the firm portfolio or products of other firms in the industry (Greenstein and Wade 1998, de Figueiredo and Kyle 2006). Conversely, a product stays on the market longer when offered by a pioneering and innovative firm (Stavins 1995), by a firm that recently entered the market (Bayus 1998), or by a firm with a strong brand and large market share (de Figueiredo and Kyle 2006). Moreover, the speed of the product life cycle apparently does not accelerate with maturation of technology (Bayus 1998, Greenstein and Wade 1998).

These studies show that product longevity is potentially affected by three general types of factors: product characteristics, industry conditions, and firm strategy. However, we know very little about whether product demography varies across organizational contexts, despite the obvious fact that product launch and withdrawal decisions are made within formal organizational structures that can differ dramatically and have been shown to affect many major decisions within firms. The core intuition we develop here sees an organization's entry mode as central to product longevity.

Exactly how entry mode might affect product demography is far from obvious. Consider, for instance, the longevity of a product on the market. A common intuition suggests that technically superior products should remain viable longer than technically inferior products. Yet, as we document below for optical disk drives

(ODDs), although *de novo* firms typically introduce technically superior products (Khessina 2003), their products do not necessarily stay on the market longer. Why? In our view, the answer contains three parts. First, *de novo* firms usually project a stronger market-specific identity, leading to a narrower screening of product offerings on the basis of technological performance. Second, *de alio* firms typically have superior resources and capabilities at time of entry. Third, *de alio* firms evaluate their products' performance more broadly in the context of the other activities of the firm (e.g., market presence, reputation, cross-subsidy of other lines of business, etc.).

To explain better, we develop theoretical ideas about product longevity by entry mode by drawing on theories about organizational identity, resources, and capabilities. Using hazard function models, we then analyze the effects of organizational entry mode on product longevities in the worldwide ODD market from 1983–1999. The findings show that entry mode does shape a firm's product demography, above and beyond the effects of product characteristics, industry conditions, and firm strategy. Moreover, we show that entry mode is more tightly linked to product exit when it is associated with firm exit, thereby strengthening the suggestion that product demography operates as a mechanism behind entry mode processes.

Optical Disk Drive Industry

Our empirical context is the ODD industry. Following periods dominated by floppy drives and hard disk drives, ODDs now come as standard equipment on many personal computers.[1] However, knowledge about the technology and industry appears limited. So, we briefly review the technology and its industrial context, focusing on aspects that come into play in our analysis.

Technology. Production of an ODD defines membership in the organizational population we investigate. The ODD is one of several main devices (including hard disk drives, floppy disk drives, tape drives, hard disk arrays, USB flash drives) used for the storage and retrieval of electronic information. By design, the optical method for data storage relies on the help of a laser for the recording and retrieval of information. Accordingly, the scientific foundations of optical drives reside in optics and physics, as opposed to the surface science underlying hard disk drives (Esener 1999).

ODD systems consist of two main components: (1) a disk for storage and (2) a drive for recording, retrieval, and output. Drive-based optical recording and information retrieval proceed as follows. Information is stored on a polycarbonate disk in the form of holes called *pits*. During recording, pits are generated by a laser beam. The stored digital information can later be retrieved by a drive. The drive's optical pickup creates a laser beam directed at the spinning disk. Logic timing circuits register the difference between the distance the light travels when it strikes pits and the distance the light travels when it strikes disk areas with no pits. The reflected signals correspond to the binary coding of 1s and 0s. These signals are then directed to a processor that reads the reflection and converts it into a stream of digital pulses, which, in turn, are converted into text, pictures, or sounds (Purcell 2000).

Capsule History of Optical Data Storage Technology. In 1972, Philips announced a method of optical storage of audio content based on analog modulation techniques. Analog modulation was soon abandoned in favor of digital signal encoding methods. During the same period, Sony undertook research to perfect error-correction methods that could be applied to digitally encoded audio. Collaboration between Sony and Philips resulted in the merging of Philips's signal format with Sony's error-correction method. In June of 1980, the two companies introduced the compact disc digital audio system.

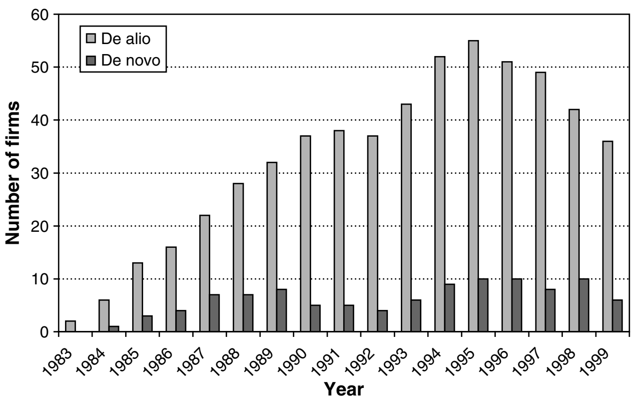
To develop techniques for storing data on disk, Philips, Sony, NEC, and other companies attempted parallels to the optical method for audio storage. These efforts resulted in the first ODD format designed for data storage that was shipped to the market in 1983. Compact disk read only memory (CD-ROM) format, tagged Yellow Book, was introduced soon after in 1985. Initially, the costs and dismal performance of CD-ROM discouraged many potential users, although further development drove costs down and improved performance. In 1986, a number of industry representatives agreed on a common file system structure that became known as the High Sierra format. This format grew popular, and was adopted as the ISO 9660 standard in 1988. ISO certification stimulated the development of CD-ROM technology because it facilitated compatibility among different producers (Disk/Trend, Inc. 1985–1999, Purcell 2000).

The next-generation device, introduced in 1984, provided a flexible write-once, read-many capability. End-users could then record and playback computer data from the same drive. The third generation optical drives, today's rewritable systems, were introduced in 1988. They offer record, playback, and erase capabilities (Disk/Trend, Inc. 1985–1988).

In early 1995, two different digital videodisk formats emerged. Toshiba led a camp of companies using the Super Density format. Sony and Philips devised their own approach—the MultiMedia compact disc. At the end of year, the charter for the DVD consortium was drawn up and dissension over format diminished as the standard for the DVD was formalized. The first DVD players were shipped in 1996 (Disk/Trend, Inc. 1996, Purcell 2000).

Over the years, manufacturers promoted other types of optical storage products that did not succeed, but often

Figure 1 Annual Number of Firms Operating by Entry Mode



instigated format wars. Wide compatibility among different producers was achieved in 2000, when 17 CD and DVD drive manufacturers, representing more than 90% of all optical drive shipments worldwide, complied with the MultiRead specification developed and promoted by the Optical Storage Technology Association (Taylor et al. 2006).

Corporate Demographics. Firms with both types of entry modes have long populated the optical storage industry. As Figure 1 shows, the characteristic distribution historically consists of a preponderance of *de alio* entrants coupled with a small number of *de novo* start-ups (data sources are discussed below). For the period we study, 86 firms entered the market *de alio* and 49 exited, while 23 *de novos* entered and 17 exited. Of the 86 *de alio* firms, 83 came into the ODD industry from related industries: computers and computer peripherals, consumer electronics, electronic and electrical components, and optics.

Background on Organizational Entry Mode

A significant body of research in organization theory, perhaps best called *corporate demography*, focuses on the *de novo* and *de alio* distinction among firms and seeks to understand how the entry mode of a firm affects its organization-level outcomes (see Carroll and Hannan 2000).[2] A basic insight holds that *de alio* companies enjoy significant advantages in performance and survival because at the time of entry they have more resources and greater experience than *de novo* firms. This expectation agrees with the pattern of findings of empirical studies conducted on multiple industries and organizational populations in different countries and time periods. For example, *de alio* firms display significantly lower mortality rates than *de novo* firms in the population of American labor unions (Hannan and Freeman 1988), in the U.S. semiconductor industry (Freeman 1990, Barnett and Freeman 2001), in the population of new firms in West Germany (Bruderl et al. 1992), in the U.S. automobile industry (Rao 1994, Carroll et al. 1996); in the population of Manhattan facsimile transmission service organizations (Baum et al. 1995), in the British, French, and German automobile industries (Hannan et al. 1998, Dobrev et al. 2001), in the U.S. television receiver industry (Klepper and Simons 2000), and in the U.S. computer manufacturing industry (Swanson 2002, Barnett et al. 2003). *De alio* firms also experience higher market shares in the U.S. television receiver industry (Klepper and Simons 2000).

In developing this basic insight about entry mode, Carroll et al. (1996) argued that *de novo* firms are more flexible, and that this flexibility might shift the advantage to *de novo* firms over time if the environment changes fast enough. Subsequent empirical studies show support for this claim: Initially higher mortality rates of *de novo* firms converge to those of *de alio* firms with organizational age in the U.S. automobile industry (Carroll et al. 1996), in the British, French, and German automobile industries (Hannan et al. 1998), and in the U.S. medical equipment industry (Mitchell 1994). *De novo* firms also show a propensity to innovate at a higher rate than *de alio* firms in the worldwide ODD industry, even years after entry (Khessina 2003).

Despite ample empirical research, little is known about mechanisms by which entry mode produces differences in organization-level outcomes between *de novo* and *de alio* firms. We believe that product demography can be one possible set of such mechanisms.

Theory

Our analysis of product demography focuses primarily on the rate of a product's exit from the market, viewed conversely as a product's longevity in the marketplace. We find it useful to think of product longevity as resulting from two different kinds of general forces (1) market forces that determine the viability of the product as an attractive choice relative to other options available to buyers and (2) internal organizational forces that encourage a firm's decision makers to leave the product on the market even after its market viability has diminished below the normal threshold. Theoretical arguments about both types of forces must be considered to make predictions about a product's longevity or rate of exit. We propose generally that products made by *de alio* and *de novo* firms differ in their rates of exit because mechanisms driven by resources, capabilities, and identities affect both market and internal organizational forces.

Resources. Resource differences are commonly invoked to explain a well-established pattern of higher mortality by *de novo* firms: At time of entry *de novo* firms typically have fewer resources than *de alio* firms. Abundant resources provide an entrant a longer period of immunity from market forces, and allow the firm more time to establish its suppliers, production system, and customer base.

Capabilities. De novo firms also display less developed capabilities than *de alio* firms at time of entry. Firms with highly developed capabilities provide accountable and reliable performance (Hannan and Freeman 1984) and acquire positional advantages, such as status, market power, and political influence (Podolny 1993, Barnett 1997). However, even advantageous capabilities can become constraints in certain contexts (Leonard-Barton 1992). The net benefits conveyed by capabilities depend not only on the level of their development, but also on a firm's ability to alter them to reflect the demands of the changing environment, i.e., on structural flexibility. Oddly enough, the lack of well-developed capabilities implies that *de novo* firms are more structurally flexible (Carroll et al. 1996, Khessina 2003).

Identities. A less obvious but potentially important difference between *de novo* and *de alio* firms concerns the identities they project and the associated behaviors of those involved with the firms, both internally and externally. In the view of McKendrick and colleagues (McKendrick and Carroll 2001, McKendrick et al. 2003), *de alio* entrants typically derive their primary identities from activities outside the focal market. De novo firms therefore project identities more clearly focused on the new market and its participants and gatekeepers. This difference matters because perceptually focused identities are thought to be important for a variety of mutually reinforcing reasons:

> First, focused identities mean that both insiders and outsiders will be more likely to recognize and identify something distinctive. So, focus increases salience. Second, the greater homogeneity of organizations with focused identities implies that form boundaries and exclusion rules are simpler. Simpler boundary rules make policing or sanctioning possible (Zuckerman 1999). Third, salience and homogeneity provide the seedbed for generating solidarity and organizing for self-promotion and defense (Buechler 2000). (McKendrick et al. 2003, p. 66)

McKendrick et al. (2003) show in the disk array industry that the density of *de novo* firms contributes more strongly to legitimation of the organizational form than does *de alio* density or total density.

While enhanced legitimacy benefits all firms in a population, a focused identity imposes serious constraints on the actions of firms with that identity. Audiences with control over material and symbolic resources necessary for firm operation, such as investors, employees, and consumers, expect *de novo* firms to behave in certain, well-defined ways consistent with the identity. For example, a study by Barthelemy (2006) of the outsourcing of "noses" in the perfume industry reveals that *de novo* perfume houses are more likely to rely on in-house noses to develop fragrances than are *de alio* firms. He explains that this is because *de novo* firms are primarily associated with the perfume industry and seek the authenticity provided by internal sourcing, even when institutional trends move in the other direction. This authenticity proves important to the founders, financiers, distributors, and customers.

Précis. Considering how these differences in resources, capabilities, and identities operate on a product's market viability and a firm's internal propensity to maintain a low viability product leads us to several plausible predictions.

First, in markets such as optical drives where competition has a clear technological character, the identities of *de novo* firms push them to stay at the frontier of technology and to maintain a product portfolio that reflects this identity. At time of entry, *de alio* firms transfer many resources and capabilities from their parent companies, giving them an identity based partly (and perhaps mainly) on the parent company. As a result, *de alio* firms experience less pressure to demonstrate their ability and promise in the focal industry. By contrast, the identities of *de novo* firms, being tightly linked to the focal industry, prompt them to offer products at the technological frontier to meet expectations of resource-holding audiences, irrespective of whether the technological position improves actual market viability. The pressure for faster product turnaround to keep up with the shifting technological frontier should result in shorter product lifetimes of *de novo* firms.

Second, the well-developed capabilities of *de alio* firms allow them to make products that enjoy greater market success (and do so for a longer time) than those of *de novo* firms. Specifically, the stable employment systems and manufacturing routines of *de alio* firms help them to generate products of consistent quality and reliability (Hannan and Freeman 1984). Market-based experience acquired in related industries helps *de alio* firms to effectively advertise their products (Nerkar and Roberts 2004). Parent company reputations (Kerin et al. 1996), status (Podolny 1994), and established identities as producers of related types of products (Swanson 2002) help *de alio* firms' products attract the attention of customers in a focal industry. By contrast, *de novo* firms lack well-developed manufacturing routines, market-based experience, and other complementary assets. As a result, they often create products of inconsistent quality and have difficulty distributing and promoting those products.

Third, *de alio* firms are more likely to have reasons and resources to keep less viable (underperforming) products on the market for a longer time, both intentionally and unintentionally. The overall identity of the *de novo* firm rests more squarely on the focal industry than does that of the *de alio* firm. Thus the reputational damage to the firm of offering technologically inferior products is greater for *de novo* firms. Further, *de alio* firms have more slack resources than *de novo* organizations (Stavins 1995). Slack allows these firms the luxury of keeping unviable products on the market with an intention to detect shifts in customer preferences, to erect entry barriers, or to exploit mutual forbearance (Haveman and Nonnemaker 2000, Sorenson 2000). Additionally, *de alio* firms may intentionally keep less viable products for subsidiaries or other parts of the firm that still use those products. Finally, the greater inertia of *de alio* firms may prompt them to unintentionally keep unviable products on the market. As more structurally complex and bureaucratic organizations, *de alio* firms are more likely to be concerned with sunk costs and may become subject to the bureaucratic rationalization of waiting for an unviable product to show a profit (Staw 1981).

To summarize, differences between *de novo* and *de alio* firms in resources, capabilities, and identity pressures lead us to think that

HYPOTHESIS 1. *Products offered by* de novo *firms exit the market at a higher rate than products made by* de alio *firms.*

We extend the argument by considering what happens as *de novo* firms age in the focal industry. We suspect that they experience less pressure to demonstrate their technological prowess at every moment and with every external interaction. Aging *de novo* firms also develop capabilities that may allow them to make products that become more attractive to customers (Carroll et al. 1996, Sørensen and Stuart 2000). Aging *de novo* organizations may also accumulate slack resources that would allow them to keep even unprofitable products on the market. Therefore we expect that

HYPOTHESIS 2. *The exit rate of products offered by* de novo *firms decreases as these firms age.*

Methodology

Data Sources for ODD Firms and Products

To test the hypotheses, we constructed a data set of all ODD products shipped in the worldwide market from the beginning of the industry in 1983 through 1999, the last year of full coverage from the most comprehensive source available to us. The original primary data sources are annual reports on different data storage devices, including ODDs, published by Disk/Trend, Inc. (1985–1999). The reports publish technical specifications on each product shipped by each producer of ODDs. There is also firm-level data on revenues and unit shipment for the largest firms in the industry.

We define products by industry convention. That is, we identify unique products using each company's definitions of products, based on the distinctions the company makes in its offerings to the buyer market. This approach to defining products essentially relies on the socially constructed market identities of products. In the optical drive context, products are defined as a model shipped by a firm to the market, which has a distinctive label and differs from other products in a firm's portfolio by at least one technical characteristic. On occasion, the Disk/Trend reports list announced products that never made it to market. We excluded these listings from our analysis.[3]

Starting Events of Production. We define a product's introduction by its first shipment to the customer market. The Disk/Trend reports provide information on the first customer shipment with varying degrees of precision. Disk/Trend gives some dates with precision to the month, others with precision to the quarter, and still others with precision to the year. We converted these dates to decimal years; dates given to the month were coded as occurring at the beginning of the month. Following Petersen's (1991) recommendations for dealing with time aggregation, dates given to only the quarter were coded as occurring at the midpoint of the quarter. Dates given to only the year were coded as occurring at the midpoint of the year.

Ending Events of Production. We identified a product's exit from the market by the date its shipment to retailers from the manufacturers ceases. The Disk/Trend reports do not provide exact information on the last shipment of the product. The annual report comes out in the third quarter of each year. It covers revenues and unit shipment for the previous calendar year, and firms and products for the current year. Using this information, we assumed that the last shipment of the product happens in the third quarter of the year the product is last mentioned in a Disk/Trend report, and coded product exit as happening at the midpoint of the third quarter of that year.

From 1983 to 1999, 109 firms entered the worldwide ODD industry, and 66 exited. These 109 firms shipped 1,323 products on the worldwide ODD market, of which 1,019 products exited the market. The data include 2,999 product-firm-year observations.

Operationalization of Variables

Dependent Variable. The *dependent variable* in the models we estimated in this study is the product-specific instantaneous rate of exit from the market (defined formally below). A product is considered to exit the market in year t if it is not shipped in year $t+1$. This definition of product exit was used in prior studies of product longevity (Bayus 1998, Greenstein and Wade 1998, Cottrell and Nault 2004, de Figueiredo and Kyle 2006).

Independent Variable. We operationalized the entry mode of a firm in two ways. First, we constructed a variable labeled *de novo firm dummy* that takes a value of one if a product is made by a firm that entered the industry as a start-up, and a value of zero if it is made by a firm that diversified into the industry from another market. This time-invariant variable is used to test Hypothesis 1.

The second variable weights *de novo* status by tenure of the firm in the industry.[4] This *tenure-weighted de novo variable* is calculated as $D^{w}_{jt} = \exp[-F_{jt}/10] * D_j$, where F_{jt} denotes tenure in the ODD industry for firm j at year t, and D_j denotes *de novo* entry mode for firm j. It shows whether a product is made by a diversifier (takes a value of zero) or by a start-up (takes inverted time-varying values depending on start-up age). For products made by start-ups, this variable tells how much time has elapsed since the firm was founded. The more time elapsed since a founding event, the lower the value of the *tenure-weighted de novo variable* (i.e., the closer it is to zero). The distribution of this variable across all product-year spells is skewed with the highest frequency of scores near unity. We use this variable to test Hypothesis 2, predicting that the *de novo/de alio* distinction in product longevity wears off over time.

Product Controls. Product age, measured as the number of years since a product was first shipped, is used to control for product exit because of its obsolescence (Stavins 1995).

Products designated for captive (sold primarily for use with systems offered by either the manufacturer or its subsidiaries) and noncaptive use (sold to other firms and end-users) may vary in market longevity. The greater inertia of internal markets between parent companies and their subsidiaries suggests longer life span of captive products. To control for this influence, we created a time-invariant dummy variable *captive product* that takes a value of one if a product is sold through captive channel and a value of zero otherwise.

Products compete with each other more intensely within product groups than across them (Greenstein and Wade 1998). Based on the Disk/Trend report classification of optical drives into product groups according to a product's operating mode and recording capacity, we created two sets of variables. *Operating mode* dummies (i.e., the *rewritable*, the *write once*, and the *read-only memory*) take a value of one if a product is designed for read only, write once, or rewritable operation, respectively, and zero otherwise. The *read-only memory* is as an omitted dummy in analyses.

Recording capacity of the optical disk is fixed because only a certain number of pits can be physically fitted on a disk. The number of pits that fit on a disk depends on the diameter of the disk and on recoding technology. Recoding technology can be either CD or DVD based. *DVD family drive* takes a value of one if a drive is DVD based and a value of zero otherwise to control for DVD drives' capacity to generate pits of smaller size on a disk, and therefore to record more information than CD drives.

The number of pits that fit on the disk also depends on the disk diameter. During the history of industry development, optical drives of different diameters were introduced ranging from 64 mm to 356 mm. However, market pressures for compatibility led to the acceptance of High Sierra format in 1986 and the subsequent adoption of the ISO 9660 standard in 1988 and ensured that the 120 mm drive became dominant on the market (Purcell 2000). The variable *drive diameter 120 mm/80 mm* is a dummy with a value of one if a drive is designated for 120 mm/80 mm disks and zero otherwise. This dummy was created to account for differences in recording capacity because of drive diameter.

Variable *data access time* is used to assess the technological advancement of products. Data access time is the physical operation associated with positioning the read/write head of a storage device in the proper location to read or write a particular piece of data. The seek operation generally requires varying the rotational speed of the disk in relation to the radial position of the laser read head. Technically, data access time is the sum of the average positioning time and the rotational latency (the inherent delay experienced by the laser read head when locating specified data). Data access time is an appropriate parameter to measure a product's technological advancement. During the observation period, it was one of the key indicators of ODD performance (Disk/Trend, Inc. 1999, Esener 1999, Purcell 2000).[5] Data access time is measured in milliseconds. To make the effects of product data access time across different years easily interpretable, we standardize its measure by dividing a product's data access time in each year by the industry's mean data access time in the year. In this way, the frontier moves each year as technology progresses. In general, the smaller (faster) a product's (standardized) data access time, the closer its performance to the technological frontier.

Organizational Controls. Large organizations may have products with longer market lifetimes than the products of small organizations for at least two reasons. First, large firms have a higher probability of introducing a successful product because they have the resources to produce multiple models. Second, large firms have more resources to keep unprofitable products on the market longer. Because many *de alio* firms are large and many *de novo* firms are small, we control for organizational size to separate the effect of a firm's entry mode from the effect of its size.

We construct a measure of the *firm's size* as scale of operations, specifically, as a firm's annual revenue in millions of U.S. dollars from its sale of ODDs. Disk/Trend provides precise firm-specific revenue data only for the major producers in the market: the top 10 to 20 ODD manufacturers, such as Sony, Matsushita, and Philips, which collectively represent approximately 90%

of all annual industry revenue. For nonmajor producers, Disk/Trend does not publish firm-specific revenue figures. However, it records the annual aggregate revenue of nonmajor smaller producers based on their geographic location, i.e., companies based in the United States and those not in the United States. We imputed annual revenue for each smaller producer in non-U.S. and U.S. categories by dividing total revenue of nonmajor producers in a category by the number of nonmajor producers in that category. We report the models with this variable included but do not find that it substantially affects any of the major conclusions.

Across the history of the industry, Japanese multinational firms have shipped the greatest number of products and kept the largest share of the market (Disk/Trend, Inc. 1999). Some researchers believe that Japan's strength in optical storage is a result of its long-term success in both research and manufacturing in opto-electronics (Miyazaki 1995, Esener 1996). All Japanese producers are *de alio* firms. So, the *Japanese headquarters dummy*, which takes value of one if a firm has headquarters in Japan and zero if otherwise, is used to ensure that the predicted market longevity of products made by *de alio* firms is not just a reflection of the longevity of products made by Japanese multinationals.

Two variables control for possible effects of a firm's product portfolio on its product longevity. *Firm's number of products,* defined as the number of distinct products that a firm ships to the market in a given year, is expected to increase this firm's product exit rate because multiple products in a portfolio increase the likelihood of product cannibalization (Greenstein and Wade 1998). *Firm's cumulative number of products* is the number of distinct products that a firm shipped since its entry into the industry until a given year; it measures firm production experience (Stavins 1995). The variable is lagged one year.

Publicly traded and privately held companies may differ in how long their products stay on the market. For example, publicly traded companies under pressure from shareholders may be inclined toward faster culling of old product lines. The dummy *public firm* takes a value of one in years when a company was listed as publicly traded and zero otherwise.

Firm's number of patents granted in ODD is the number of distinctive patents granted to a firm in ODD technology in a given year. Following Rosenkopf and Nerkar (2001), we defined patents as those in ODD technology if they belong to patent subclasses that cover different components of an ODD system.

Industry Controls. Several variables are used to control for industry processes. Three variables control for effects of environmental munificence on product market longevity. The variable *worldwide industry revenues* measured in millions of U.S. dollars describes the realized demand for the product. The variable *PC unit shipments* measured in millions of units provides information about the size of the key (largest) market for ODDs. *Number of patents granted in ODD technology*, which is a number of distinct patents granted in a given year in the ODD technology, measures technological munificence of the industry.

The number of products on the market creates competition for a buyer's attention (de Figueiredo and Kyle 2006). Time-varying counts of *product density* control for intensity of product competition.

To account for possible effects of population aging, including first-mover or order-of-entry advantages on product market longevity (Lieberman and Montgomery 1988), we constructed a fixed product-level variable *product's order of entry* defined as population age in the year that a product was shipped to the market for the first time. Count of years starts in 1983, so that a product that was introduced in 1983 is assigned the value of zero, a product that was introduced in 1984 is assigned a value of one and so on. The variable is time invariant.

The presence or absence of technological standards may affect product longevity on the market. The *standard ISO 9660 period dummy* takes a value of one for years 1988–1999 and zero otherwise to control for the influence of the only official standard during the observation period. Effects of other formats are captured by the variable *industry age,* which is the age of the worldwide ODD industry. Industry age variable is also meant to control for other unobserved and observed temporal changes that may affect product chances to exit the market.

Model Specification

Product exit rates are assessed using continuous-time event history analysis. We treat a product as the unit at risk, and the *dependent variable* is the instantaneous rate of a product's exit from the worldwide ODD industry, defined as

$$r(t) = \lim_{\Delta t \to 0} \frac{P[t < T < t + \Delta t \mid T > t]}{\Delta t},$$

where T is a random variable for the time of the event of interest, t is the time that a product has existed, and $P(\cdot)$ is the conditional probability of the product's exit from the market over the interval $[t,\ t + \Delta t]$ given that the product was still on the market at time t. We use the continuous time framework because we believe it more accurately reflects the actual process we study, whereby firms might launch and withdraw products at any moment in time.

We use a *piecewise exponential* function to represent variation in the timing of product exit from the market to allow a flexible specification of product age-dependence. A *piecewise exponential* model represents a widely used strategy that splits the time axis into time pieces determined by an analyst (Carroll and Hannan 2000, pp. 136–138). After examining life tables and exploring estimates of a variety of choices of the breakpoints, we decided to break the duration scale in years at 1.0, 2.0, 3.0, 4.0, and 5.0.

The product exit rate $r(u, t)$ is specified as a function of product age (u), product contemporaneous density (N_t), entry mode of a firm that makes the product (D), and other measured covariates (X). The general class of models we estimate has the form

$$\ln r(u, t) = m_p + \beta N_{it} + \varphi D_i + \gamma X_{it},$$

where m_p denotes product age-specific effects, N_{it} denotes product density for product i at year t, D_i denotes entry mode of a firm making product i, and X_{it} summarizes time-varying covariates.

In testing the hypotheses, we estimated models using the method of maximum likelihood as implemented with a user-defined routine in STATA (Sørensen 1999). To estimate rate models with time-varying covariates, we constructed split-spell data breaking observed durations in year-long periods with the values of covariates updated every year.

Findings

The descriptive data on optical drives' data access time in Table 1 shows that *de novo* firms offer more technologically advanced products with better performance parameters and smaller distance from the technological frontier. First, *de novo* firms make products with, on average, faster data access time than *de alio* firms. Nominal data access time of *de novo* and *de alio* firms' products is 193.7 ms and 244.9 ms, respectively, whereas their standardized data access time is 0.778 and 1.02. Second, the average distance of standardized data access time of *de novo* firm's products from the technological frontier is smaller (0.699) than that of *de alio* (0.848). Third, *de novo* firms introduce products closer to their current best product in terms of standardized performance (0.207) than *de alio* firms (0.561). Finally, *de novo* firms introduce products that, on average, improve more over their previous best product in nominal data access time (26.3 ms) than de alio firms (−6.41 ms). Thus, *de novo* firms typically offer products that locate closer to the frontier and to each other than *de alio* firms.

These descriptive results are consistent with the findings of Khessina (2003) who demonstrated that in the ODD industry, *de novo* firms display an advantage at creating products with performance near the technological frontier. Her empirical analysis controlled for sample selection because of firm mortality as well as firm age, size, dominance, product portfolio, incumbency status, and country location. Khessina (2003) showed that although there is no apparent difference between *de novo* and *de alio* firms in the overall rate of product introduction, *de novo* firms introduce more products with data access time faster than the industry mean, and products with data access time in the top 15%, 20%, and 25% of industry performance distribution.

Table 2 provides descriptive statistics of the split-spell file used for event history analysis. The file contains multiple spells for each product, so it does not always intuitively reflect the experiences of products on the market. From 1983 to 1999, 1,201 *de alio* and 122 *de novo* products were shipped on the ODD market, of which 916 *de alio* and 103 *de novo* products exited the market.

Table 3 presents the estimates of the piecewise-exponential rate models of the exit of products from the worldwide ODD market from 1983 through 1999. Model 3.1 in Table 3 shows support for Hypothesis 1: De novo firms' products have a significantly higher probability of exiting the market than *de alio* firms' products.

Table 1 Comparison of Products of *De Novo* and *De Alio* Firms

	De Novo		*De Alio*	
Variables	Mean	Std. dev.	Mean	Std. dev.
Product age at last observation (includes both censored and uncensored cases)	1.25	1.45	1.44	1.42
Firm size at time of product entry	9.94	9.00	232.5	290.2
Data access time of optical drive product [in ms]	193.7	118.5	244.9	267.9
Data access time standardized	0.778	0.454	1.02	0.908
Distance of data access time of optical drive product from the industry frontier at time of product entry	0.699	0.430	0.848	0.782
Distance of data access time of optical drive product from the firm's best optical drive at time of product entry (excludes single-product firms)	0.207	0.300	0.561	0.817
Percentage of optical drive products that represent the firm's best optical drive at time of product entry (excludes single-product firms)	47.5		25.9	
Difference in data access time between a firm's new optical drive product and its previous best optical drive product [in ms]	26.3	123.3	−6.41	163.8
Firm's number of products	3.77	1.74	12.03	10.44

Table 2 Descriptive Statistics for ODD Products: Split-Spell File

Variables	Mean	Std. dev.	Min.	Max.
Product exit = 1	0.340	0.474	0	1
Product age at the first spell (u)	0.809[1]	1.28	0	9.38
Product age at the last spell (u)	1.44	1.42	0.042	10
Density all products (t)	267.24	97.78	3	377
Product's order of entry (u_0)	10.34	3.94	0	16
Industry revenues [in millions of U.S. dollars] (t)	4,640	2,949	2	8,764
Industry age [in years] (t)	11.43	3.53	0	16
PC unit shipments [in millions] (t)	60.38	31.29	8	113
Period dummy for standard ISO 9660 (1988–1999) = 1	0.956	0.206	0	1
Number of patents granted in ODD technology (t)	268.4	65.95	57	346
Firm's size [revenues in millions of U.S.$] ($t$)	218.27	282.86	0.3	1,079.9
Ln firm's size (t)	4.03	2.02	−1.20	6.98
Firm's number of products (t)	11.33	10.26	1	44
Firm's cumulative number of products ($t-1$)	50.31	59.16	1	279
Japanese headquarters dummy = 1	0.644	0.479	0	1
Public firm = 1 (t)	0.753	0.431	0	1
Firm's number of ODD patents granted (t)	8.74	11.85	0	55
Captive product = 1	0.176	0.380	0	1
Drive operating mode: Write once = 1	0.220	0.415	0	1
Drive operating mode: Rewritable = 1	0.266	0.442	0	1
Drive operating mode: Read only = 1 (omitted)	0.539	0.499	0	1
DVD family drive = 1	0.041	0.198	0	1
Drive data access time [in ms]	250.4	280.0	25.25	2,510
Drive data access time standardized	1	0.882	0.078	8.29
De novo data access time standardized	0.778	0.454	0.128	2.32
De alio data access time standardized	1.02	0.908	0.078	8.29
Drive diameter 120 mm/80 mm = 1	0.632	0.482	0	1
De novo entry mode dummy = 1	0.084	0.278	0	1
Tenure-weighted *de novo* variable (t)	0.069	0.234	0	1

Notes. N of products = 1,323 (*de alio* = 1,201; *de novo* = 122); N of product exits = 1,019 (*de alio* = 916; *de novo* = 103); N of product-years = 2,999 (*de alio* = 2,746; *de novo* = 253).
[1]Numbers are based on both uncensored and right-censored cases.

Model 3.2 is similar to Model 3.1, but instead of *de novo* dummy, it uses the tenure-weighted *de novo* variable, which has a significant positive effect on product exit rates. This finding shows first, that products made by *de novo* firms have higher exit rates than those made by *de alio* firms. Second, it shows that the more recently a *de novo* firm was founded, the higher the exit rates of its products. In other words, as a *de novo* firm ages in the industry, the market longevity of its products becomes similar to that of *de alio* firms. Thus, Hypothesis 2, predicting that the effect of entry mode on exit rates of products wears off with time, is supported.[6]

Next, we explore the connection between product exit and firm exit, seeking to understand how product demography might operate as a mechanism associated with *de novo* effects. During the period of observation, 66 out of 109 firms exited.[7] Only 13.5% of all product exits (138 out of 1,019 withdrawn products) were associated with these firm exits. What is the relationship between the two types of exit, if any? In our data, any time a firm exits, its products also exit. Because firm exit exactly predicts product exit, firm exit cannot be used as a right-hand side variable (see similar discussion in de Figueiredo and Kyle 2006, p. 260). But we can disaggregate the product exit event into two separate events (1) product exit simultaneous with firm exit and (2) product exit with no firm exit. Although this disaggregation appears similar to that of a competing risks setup, it differs fundamentally in that the two defined events are hierarchically related (product exit occurs in both events) rather than representing two separate paths to the same outcome. So analysis of the separate events is suggestive at best. Moreover, it makes sense to only consider firms with more than one product because product exit predicts firm exit perfectly for single-product firms.

Previous research on firm exit rates using this data shows that there is no significant effect of *de novo* status on firm disbanding (Khessina 2006). But the disaggregated product exit rates equations suggest a link through product demography. The *de novo* variable shows positive significant relationships with the joint product and firm exit event (see Model 3.3), but not with the product exit only event (see Model 3.4). This suggests a stronger association between product exit and firm exit for *de novo* firms than for *de alio*. Although in case of disbanding firms, it is impossible to determine whether products exit from the market because a firm exits the industry or whether the firm exits the industry because its products were a market failure, the descriptive data reveals some interesting associations. So, when *de novo*

Table 3 Piecewise Exponential Models of Effects of Firms' Entry Mode on Exit Rates of Optical Drive Products

	Model (3.1) Event: All product exit	Model (3.2) Event: All product exit	Model (3.3) Event: Product exit and firm exit	Model (3.4) Event: Product exit and no firm exit
Product age: $0 < u \leq 1$	−2.34*** (0.469)	−2.34*** (0.466)	−12.3*** (1.93)	−2.87*** (0.575)
Product age: $1 < u \leq 2$	−0.446 (0.475)	−0.444 (0.472)	−9.60*** (1.94)	−1.06 (0.581)
Product age: $2 < u \leq 3$	0.795 (0.513)	0.799 (0.511)	−7.87*** (2.17)	0.171 (0.614)
Product age: $3 < u \leq 4$	1.99** (0.573)	2.00*** (0.572)	−6.93** (2.32)	1.27 (0.669)
Product age: $4 < u \leq 5$	2.99*** (0.666)	3.00*** (0.665)	−4.43 (2.84)	2.19** (0.762)
Product age: $u > 5$	4.38*** (0.689)	4.39*** (0.688)	−1.66 (2.88)	3.28*** (0.794)
Density all products (t)	0.021*** (0.002)	0.021*** (0.002)	0.033*** (0.008)	0.019*** (0.002)
Product's order of entry (u_0)	0.980*** (0.085)	0.981*** (0.085)	1.49*** (0.339)	0.929*** (0.093)
Worldwide industry revenues [in millions of U.S.$] ($t$)	0.0002* (0.000)	0.0002* (0.000)	0.001** (0.000)	0.000 (0.000)
Industry age/year (t)	−1.07*** (0.180)	−1.07*** (0.180)	−3.07*** (0.760)	−0.889*** (0.203)
PC unit shipments [in million units] (t)	−0.068*** (0.016)	−0.068*** (0.016)	−0.036 (0.067)	−0.072*** (0.018)
Standard ISO 9660 period dummy = 1	−1.25** (0.477)	−1.24** (0.477)	15.2*** (1.37)	−1.46** (0.542)
Number of patents granted in ODD technology (t)	0.002 (0.001)	0.002 (0.001)	0.020*** (0.005)	0.001 (0.001)
Ln firm's size [in millions of U.S.$] ($t$)	−0.045 (0.033)	−0.046 (0.033)	−0.666*** (0.111)	0.020 (0.036)
Firm's number of products (t)	0.006 (0.007)	0.006 (0.007)	−0.455*** (0.058)	0.009 (0.007)
Firm's cumulative number of products ($t-1$)	−0.0002 (0.002)	0.0002 (0.002)	0.013 (0.007)	0.000 (0.002)
Japanese headquarters dummy = 1	−0.276** (0.097)	−0.277** (0.097)	−0.521 (0.480)	−0.226* (0.108)
Public firm = 1 (t)	0.303** (0.111)	0.308** (0.111)	0.272 (0.342)	0.330* (0.133)
Firm's number of ODD patents granted (t)	−0.013* (0.006)	−0.013* (0.006)	0.096*** (0.023)	−0.020** (0.006)
Captive product = 1	0.027 (0.111)	0.022 (0.112)	−0.233 (0.709)	−0.040 (0.118)
Operating mode: Write once = 1	−0.541*** (0.134)	−0.542*** (0.134)	−2.64** (0.960)	−0.419** (0.142)
Operating mode: Rewritable = 1	−0.358* (0.160)	−0.351* (0.160)	−2.68 (1.52)	−0.293 (0.165)
DVD family drive = 1	0.035 (0.230)	0.036 (0.230)	−12.4*** (0.609)	0.037 (0.235)
Product's access time (t) [standardized]	0.296* (0.147)	0.293* (0.147)	−0.897 (1.45)	0.356* (0.146)
Drive diameter 120 mm/80 mm = 1	1.07*** (0.214)	1.06*** (0.214)	−0.963 (1.68)	1.11*** (0.231)
Drive diameter 120 mm/80 mm ∗ Product's access time	−0.438** (0.155)	−0.434** (0.155)	0.764 (1.49)	−0.486** (0.159)
De novo firm dummy = 1	0.294* (0.140)			
Tenure-weighted *de novo* variable (t)		0.384* (0.164)	0.940** (0.355)	0.037 (0.216)
Number of products	1,126	1,126	1,103	1,103
Number of product exits	889	889	94	767
Number of product-year observations	2,545	2,545	2,448	2,448
Log pseudolikelihood	−1,009.11	−1,008.76	−134.2	−995.3
Wald chi-square	927.85	931.04	3,473.8	750.7
(d.f.)	(27)	(27)	(27)	(27)

Note. Robust standard errors shown in parentheses.
$p^{*} < 0.05$; $p^{**} < 0.01$; $p^{***} < 0.001$.

products exit the market, 16.5% (14.1% excluding firm exits by mergers and acquisitions of the time the firm also exits, whereas for *de alio* firms, the corresponding number is 5.3% (5.0%). Interestingly enough, the average dying *de novo* firm has 2.00 (2.12) products on the market at the time of its exit, while the average dying *de alio* offers only 1.77 (1.74).

Discussion

At the outset, we proposed that product demography may be a mechanism that translates initial differences in resource endowments and previous experiences between *de novo* and *de alio* firms into survival and performance outcomes. Two findings lend support to this idea. First, we find a tighter association between product exit and firm exit for *de novo* than for *de alio* firms. Second, we also find that *de novo* firms' products exit the market at a significantly higher rate than *de alio* firms'.

Why do products of *de novo* firms experience shorter market longevity than those of *de alio* firms? We theorized that differences in resources, capabilities, and identities combine in their impact on product market longevity. For example, we argued that higher exit rates of *de novo* firms' products may result from identity pressures to turnaround products quickly in an attempt to keep up with the shifting technological frontier. Supporting this idea, we found that *de novo* firms tend to offer products closer to the technological frontier and to compete mostly in the range of technologically advanced products, whereas *de alio* firms compete over a wider range of product performance distribution. Yet, identity is only part of the story.

Identity-based pressures likely operate on firms in the launching of new products. While all firms need to attract investors, employees, suppliers, and customers, *de alio* firms come to the market initially with histories, reputations, and resources; *de novo* firms do not. Accordingly, *de novo* firms need to demonstrate more clearly early on (perhaps before actual entry) that they can compete effectively. When competition takes a technological character, *de novo* firms should therefore face more rigorous screening on the basis of the technical qualities in the initial start-up phase, and should exhibit more advanced technical properties at entry. Moreover, once established, this difference should persist. A firm founded as a technological leader remains under pressure to maintain a position in that realm: It is benchmarked against its previous products and its now-public identity facilitates its renewal. Failure to meet these expectations likely results in difficulty in promoting new products to customers.

Identity pressures alone cannot, however, explain how *de novo* firms manage to introduce technologically advanced products. Introduction of such products demands capabilities designed for product innovation (Sørensen and Stuart 2000). De novo firms are more likely to develop such capabilities than *de alio* firms for two reasons. First, because imprinting of *de novo* firms happens in the focal industry (Stinchcombe 1965), their capabilities are likely to closely reflect technological demands of this industry. Second, because at the time of entry into a focal industry, *de alio* firms transfer routines and structures from their parent companies, they tend to be more architecturally complex than *de novo* firms and, consequently, more inertial in their abilities to change (Hannan et al. 2003a, b). Thus, *de novo* firms not only develop capabilities better attuned to the focal technological environment, but are also more capable of changing them if the environment shifts. As a result, they are more capable of continuously offering technologically advanced products (Khessina 2003). By contrast, *de alio* firms have better developed manufacturing, marketing, and distribution capabilities that help them offer products that are more likely to succeed, and, as a result, to have a longer market life. Thus, both forces of identity pressures and capabilities are needed to explain greater market exit rates of *de novo* firms' products.

The analyses reveal additional support for the ideas that identity pressures and organizational capabilities play a large role in product market longevity. For example, Model 3.1 shows that products offered by public firms have the shorter market life than those offered by private firms. This finding can be interpreted as offering extra support to the identity pressures idea. Public companies are generally under greater social scrutiny than private firms and may be expected to behave in certain ways in specific industries by shareholders with particular interests in those industries. For instance, shareholders may pressure public companies to offer products at the technological frontier, and as a result, to quickly turnaround products in their existing portfolios. Some extra support for the capability idea can also be seen in Model 3.1. It shows the greater market longevity of products made by firms with a larger number of patents in optical technology (a type of capability) and by Japanese firms renowned for their research, manufacturing, and marketing capabilities in optoelectronics.

The important role of identity pressures and organizational capabilities behind differences in product longevity between *de novo* and *de alio* firms should attenuate as firms age in the focal industry. Over time, identity pressures on surviving *de novo* firms become less fierce as organizations develop manufacturing, marketing, and distribution capabilities that allow them to offer products with a greater likelihood of market success. Supporting this idea, we found that the exit rate of *de novo* firms' products converge with that of *de alio* firms', as the firms grow older in the industry. This finding is consistent with studies showing that the mortality rate of *de novo* firms converges over time with that of *de alio* organizations (Carroll et al. 1996, Hannan et al. 1998). It thus provides additional indirect support to the idea of product demography as a mechanism behind entry mode effect on organizational survival.

Identity and capabilities are not the only driving forces behind a longer market life of *de alio* firms' products. We theorized that *de alio* firms have reasons and resources to keep on the market products that are no longer individually viable. Specifically, we suggested that three internal processes can either prompt or enable a firm to keep unviable products on the market: slack resources, captive production, and structural inertia. A number of controls in empirical models provide proxies for these processes. The variables measuring firm revenues, size of a firm's product portfolio, and a firm's number of patents can be considered a proxy for slack resources. Captive product dummy controls for captive production; and the variables measuring firm public status, revenues, and cumulative number of products provide a proxy for firm structural inertia. Even controlling for all these variables, *de alio* firms' products still show a significantly lower rate of market exit. Thus the longevity of *de alio* products seem to be driven less by a firm's intentional or unintentional decisions to keep even unprofitable products on the market, but more by actual product market success. Additionally, statistical results reveal that the role of observable resources may be not strong. The following variables, which are often used to measure resources, do not significantly affect product longevity in fully specified models: firm size (measured by revenues) and firm number of products. Not all resources, of course, are captured by these variables, but the findings, nevertheless, suggest the necessity to look deeper into the issue.

Although the data are not detailed enough to adjudicate among the processes of identity, capabilities, and resources behind differences in product demography between *de novo* and *de alio* firms, it seems that identity pressures and capabilities play a greater role than resources. On the other hand, capabilities are often tied to resources. It is possible that resources still play a key role but indirectly, through the impact of capabilities. Overall, because the evidence is indirect, further investigation is needed before any firm conclusions can be made.

Other limitations of this study are common to single-industry research. While having data on all products shipped in the ODD industry from its beginning in 1983 through 1999 allowed us to avoid survivor and selection biases in the statistical analyses, there is always a question as to what extent our findings are generalizable to other industries. For example, we argue that focused identity of *de novo* firms affects their product demography by prompting start-ups to offer products at the technological frontier. In the context of this study, i.e., the ODD industry, *de novo* firms' identity has a well-defined technological character. However, *de novo* firms' identity basis can be quite different in slow-paced low-technology industries, and consequently, may not affect product demography in the same way as in high-velocity high-technology markets.

Capital intensity of the ODD industry may uniquely shape firms' product demography. Although ODD production may not be as capital intensive as that of hard disk drives (McKendrick et al. 2000, Noble 2000), it still requires significant financial investment, compared to many other industries (Esener 1999). Capital intensity is driven by expensive intellectual property and high licensing fees, costly R&D expenditures, and the need for scale in production to achieve decent margins (Saxonhouse 1996, Esener 1999, Noble 2000). Thus, it is not surprising that the number of *de novo* entrants into the industry constitutes only 27% of all entry, lower than the average of 55% across different manufacturing industries (Dunne et al. 1988). It also explains why the only countries that experienced a sizeable number of *de novo* entries were those with either established venture capital and/or governmental support. For instance, the United States hosted 11 and Taiwan produced 9 *de novo* firms of a total 23 that entered the industry during the observation period.

Given that capital intensity of the industry apparently deters start-ups, a question relevant to this study concerns whether these capital requirements might have affected product demography. For example, the prowess of *de novo* firms to offer products at the technological frontier may result from a narrower and more rigorous initial technical screening by capital holding audiences. Similarly, shorter market longevity of *de novo* firms' products (if treated as an indicator of lesser market success) can be explained by the new firms' difficulty of obtaining enough capital to effectively develop and market their products. Entry mode may shape product demography differently in industries with either much higher or much lower capital requirements. Further research on other industries is needed to confirm or refute these issues.

Acknowledgments
The study described in this paper originated as part of a research program directed by David McKendrick, under the auspices of the Information Storage Industry Center, University of California, San Diego. Helpful comments from John Freeman, Bronwyn Hall, Michael Hannan, Russell Hudson, James Lincoln, David McKendrick, David Mowery, Trond Petersen, Jesper Sørensen, Olav Sorenson, and three anonymous reviewers are greatly appreciated.

Endnotes

[1]As with hard disk drives, ODDs are designed for data storage and retrieval. Optical drives rest on a very different technology, however. Hard drives use magnetic methods of recording and usually stay fixed within a computer, whereas optical drives are based on the laser beam method of recording and serve as removable data storage. The distinct industries that developed around the two technologies differ both in organizational membership and in historical timing. Management scholars have studied the hard disk drive industry extensively (e.g., Christensen and Rosenbloom 1995, Lerner 1997, McKendrick et al. 2000, King and Tucci 2002, Agarwal et al. 2004, Barnett and McKendrick 2004), but ODDs have received far less attention (but see Rosenkopf and Nerkar 2001; Khessina 2003, 2006).

[2]This research should not be confused with that from the tradition examining entrants and incumbents (e.g., Tushman and Anderson 1986, Henderson and Clark 1990). Although the two distinctions are sometimes (mistakenly) conflated, no direct parallels should be drawn between entrants and *de novo* firms, on the one hand, and incumbents and *de alio* firms, on the other hand. Incumbency status (incumbents versus entrants) and entry mode (*de alio* versus *de novo*) differ in fundamental ways. Incumbency status indicates *when* a firm enters a focal industry (i.e., before or after a technological discontinuity). In contrast, entry mode indicates *how* a firm enters a focal industry. In models not reported here, we controlled for incumbency status. All results remained robust to this specification.

[3]Specifically, we did not code (1) products listed as preliminary specification and (2) products when the announced date of the first customer shipment came after the date of the last customer shipment.

[4]We cannot model firm tenure as an independent covariate by means of time pieces in the piecewise exponential models, because we use time pieces to model product age.

[5]Technically, market attractiveness of an ODD is defined not only by its time performance, but also by its recording capacity. Historically, however, time performance parameters have

turned out to be much more decisive than recording capacity in defining the attractiveness of ODDs to users, and in shaping their chances to compete with other types of drives, e.g., hard drives (Disk/Trend, Inc. 1999, Merrill Lynch, Co., McKinsey and Company 2001).

[6]In additional analysis not reported in detail here, we also estimated (at the request of a reviewer) models with controls for overall firm tenure, and with a tenure-weighted *de alio* variable. These estimates agree with and confirm the conclusions adopted here; namely, that the tenure-weighted *de novo* effect is distinct from any overall effect of firm tenure and that its effect is bigger than that of the tenure-weighted *de alio* variable, especially in early product years (the effects converge over time).

[7]Of these exits, a total of 7 resulted from mergers or acquisitions; only 11 products (1.1% of all product exits) were associated with mergers or acquisitions.

References

Agarwal, R., R. Echambadi, A. M. Franco, M. B. Sarkar. 2004. Knowledge transfer through inheritance: Spin-out generation, development, and survival. *Acad. Management J.* **47** 501–522.

Barnett, W. P. 1997. The dynamics of competitive intensity. *Admin. Sci. Quart.* **42** 128–160.

Barnett, W. P., J. Freeman. 2001. Too much of a good thing? Product proliferation and organizational failure. *Organ. Sci.* **12**(5) 539–558.

Barnett, W. P., D. G. McKendrick. 2004. Why are some organizations more competitive than others? Evidence from a changing global market. *Admin. Sci. Quart.* **49** 535–571.

Barnett, W. P., A.-N. Swanson, O. Sorenson. 2003. Asymmetric selection among organizations. *Indust. Corporate Change* **12** 673–695.

Barthelemy, J. 2006. Sourcing in noses in the fragrance industry across its history. Unpublished manuscript, ESSEC, Paris, France.

Baum, J. A. C., H. J. Korn, S. Kotha. 1995. Dominant designs and population dynamics in telecommunications services: Founding and failure of facsimile transmission service organizations, 1965–1992. *Soc. Sci. Res.* **24** 97–135.

Bayus, B. L. 1998. An analysis of product lifetimes in a technologically dynamic industry. *Management Sci.* **44**(6) 763–775.

Bruderl, J., R. Schussler. 1990. Organizational mortality: The liabilities of newness and adolescence. *Admin. Sci. Quart.* **35** 530–547.

Bruderl, J., P. Preisendorfer, R. Ziegler. 1992. Survival chances of newly founded business organizations. *Amer. Sociol. Rev.* **57** 227–242.

Buechler, S. M. 2000. *Social Movements in Advanced Capitalism: The Political Economy and Social Contraction of Activism*. Oxford University Press, New York.

Carroll, G. R., M. T. Hannan. 2000. *The Demography of Corporations and Industries*. Princeton Press, Princeton, NJ.

Carroll, G. R., O. M. Khessina. 2005. The ecology of entrepreneurship. S. A. Alvarez, R. Agarwal, O. Sorenson, eds. *Handbook of Entrepreneurship Research: Disciplinary Perspectives*. Springer, New York, 167–200.

Carroll, G. R., L. S. Bigelow, M.-D. L. Seidel, L. B. Tsai. 1996. The fates of *de novo* and *de alio* producers in the American automobile industry, 1885–1981. *Strategic Management J.* **17** 117–137.

Christensen, C. M., R. S. Rosenbloom. 1995. Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value networks. *Res. Policy* **24** 233–257.

Cottrell, T., B. R. Nault. 2004. Product variety and firm survival in the microcomputer software industry. *Strategic Management J.* **25** 1005–1025.

de Figueiredo, J. M., M. K. Kyle. 2006. Surviving the gales of creative destruction: The determinants of product turnover. *Strategic Management J.* **27** 241–264.

Disk/Trend, Inc. 1985–1999. *Disk/Trend Report: Optical Disk Drives*. Disk/Trend, Inc., Mountain View, CA.

Dobrev, S. D., T. Kim, M. T. Hannan. 2001. Dynamics of niche width and resource partitioning. *Amer. J. Sociol.* **106** 1299–1337.

Dunne, T., M. J. Roberts, L. Samuelson. 1988. Patterns of firm entry and exit in U.S. manufacturing industries. *RAND J. Econom.* **19** 495–515.

Esener, S. C. 1996. Optical storage technology. S. Forrest, ed. *Optoelectronics in Japan and the United States*. JTEC Panel Report, International Technology Research Institute, Loyola College, Baltimore, MD, 35–64.

Esener, S. C. 1999. Introduction-optical storage. S. C. Esener, M. H. Kryder, eds. *The Future of Data Storage Technologies*. WTEC Panel Report, WTEC Hyper-Librarian, International Technology Research Institute, Loyola College, Baltimore, MD, 1–9.

Freeman, J. 1990. Ecological analysis of semiconductor firm mortality. J. V. Singh, ed. *Organizational Evolution: New Directions*. Sage Publications, Newbury Park, CA, 53–77.

Greenstein, S. M., J. B. Wade. 1998. The product life cycle in the commercial mainframe computer market, 1968–1982. *RAND J. Econom.* **29** 772–789.

Hannan, M. T., J. Freeman. 1984. Structural inertia and organizational change. *Amer. Sociol. Rev.* **49** 149–164.

Hannan, M. T., J. Freeman. 1988. The ecology of organizational mortality: American labor unions, 1836–1985. *Amer. J. Sociol.* **94** 25–52.

Hannan, M. T., L. Pólos, G. R. Carroll. 2003a. Cascading organizational change. *Organ. Sci.* **14**(5) 463–482.

Hannan, M. T., L. Pólos, G. R. Carroll. 2003b. The fog of change: Opacity and asperity in organizations. *Admin. Sci. Quart.* **48** 399–432.

Hannan, M. T., G. R. Carroll, S. D. Dobrev, J. Han. 1998. Organizational mortality in European and American automobile industries, Part I: Revisiting the effects of age and size. *Eur. Sociol. Rev.* **14** 279–302.

Haveman, H. A., L. Nonnemaker. 2000. Competition in multiple geographic markets: The impact on growth and market entry. *Admin. Sci. Quart.* **45** 232–267.

Henderson, R. M., K. B. Clark. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Admin. Sci. Quart.* **35** 9–30.

Kerin, R. A., G. Kalyanaram, D. J. Howard. 1996. Product hierarchy and brand strategy influences on the order of entry effect for consumer packaged goods. *J. Product Innovation Management* **13** 21–34.

Khessina, O. M. 2003. Entry mode, technological innovation and firm survival in the worldwide optical disk drive industry, 1983–1999. Unpublished doctoral dissertation, University of California, Berkeley, CA.

Khessina, O. M. 2006. Direct and indirect effects of product portfolio on firm survival in the worldwide optical disk drive industry, 1983–1999. J. A. C. Baum, S. D. Dobrev, A. van Witteloostujin, eds. *Ecology and Strategy: Adv. Strategic Management*, Vol. 23. JAI, Oxford, UK, 591–630.

King, A. A., C. L. Tucci. 2002. Incumbent entry into new market niches: The role of experience and managerial choice in the creation of dynamic capabilities. *Management Sci.* **48**(2) 171–186.

Klepper, S., K. L. Simons. 2000. Dominance by birthright: Entry of prior radio producers and competitive ramifications in the U.S. television receiver industry. *Strategic Management J.* **21** 997–1016.

Leonard-Barton, D. 1992. Core capabilities and core rigidi ties: A paradox in managing new product development. *Strategic Management J.* **13** S111–S125.

Lerner, J. 1997. An empirical analysis of a technology race. *RAND J. Econom.* **28** 228–247.

Lieberman, M., B. Montgomery. 1988. First-mover advantages. *Strategic Management J.* **9** S41–S58.

McKendrick, D. G., G. R. Carroll. 2001. On the genesis of organizational forms: Evidence from the market for disk drive arrays. *Organ. Sci.* **12**(6) 661–682.

McKendrick, D. G., R. F. Donner, S. Haggard. 2000. *From Silicon Valley to Singapore: Location and Competitive Advantage in the Hard Disk Drive Industry*. Stanford University Press, Stanford, CA.

McKendrick, D. G., J. Jaffee, G. R. Carroll, O. M. Khessina. 2003. In the bud? Analysis of disk array producers as a (possibly) emergent organizational form. *Admin. Sci. Quart.* **48** 60–93.

Merrill Lynch and Co., McKinsey and Company. 2001. The storage report—Customer perspectives and industry evolution. Special report of a joint industry study.

Mitchell, W. 1994. The dynamics of evolving markets: The effects of business sales and age on dissolutions and divestitures. *Admin. Sci. Quart.* **39** 575–602.

Miyazaki, K. 1995. *Building Competencies in the Firm: Lessons from Japanese and European Optoelectronics*. St. Martin's Press, New York.

Nerkar, A., P. W. Roberts. 2004. Technological and product-market experience and the success of new product introductions in the pharmaceutical industry. *Strategic Management J.* **25** 779–799.

Noble, G. W. 2000. Conspicuous failures and hidden strengths of the ITRI model: Taiwan's technology policy toward hard disk drives and CD-ROMs. Report 2000–02, The Information Storage Industry Center, University of California, San Diego, CA.

Petersen, T. 1991. Time-aggregation bias in continuous-time hazard-rate models. P. Masden, ed. *Sociological Methodology*, Vol. 21. Basil Blackwell, Oxford, UK, 263–290.

Podolny, J. M. 1993. A status-based model of market competition. *Amer. J. Sociol.* **98** 829–872.

Podolny, J. M. 1994. Market uncertainty and the social character of economic exchange. *Admin. Sci. Quart.* **39** 458–483.

Purcell, L. 2000. *CD-R/DVD: Disc Recording Demystified*. McGraw-Hill, New York.

Rao, H. 1994. The social construction of reputation: Certification contests, legitimation, and the survival of organizations in the American automobile industry: 1895–1912. *Strategic Management J.* **15** 29–44.

Rosenkopf, L., A. Nerkar. 2001. Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management J.* **22** 287–306.

Saxonhouse, G. R. 1996. Optoelectronics in Japan: Some economic considerations. S. Forrest, ed. *Optoelectronics in Japan and the United States*. JTEC Panel Report, International Technology Research Institute, Loyola College, Baltimore, MD, 137–162.

Sørensen, J. B. 1999. Stpiece: A program for the estimation of piecewise-constant rate hazard models in STATA 6.0. Unpublished ado-file, Graduate School of Business, University of Chicago, Chicago, IL.

Sørensen, J. B., T. E. Stuart. 2000. Aging, obsolescence, and organizational innovation. *Admin. Sci. Quart.* **45** 81–112.

Sorenson, O. 2000. Letting the market work for you: An evolutionary perspective on product strategy. *Strategic Management J.* **21** 577–592.

Stavins, J. 1995. Model entry and exit in a differentiated-product industry: The personal computer market. *Rev. Econom. Statist.* **77** 571–584.

Staw, B. M. 1981. The escalation of commitment to a course of action. *Acad. Management Rev.* **6** 577–588.

Stinchcombe, A. L. 1965. Social structure and organizations. J. G. March, ed. *Handbook of Organizations*. Rand McNally, Chicago, IL, 142–193.

Swanson, A.-N. 2002. Form coherence and the fates of *de alio* and *de novo* organizations in the U.S. digital computer industry: 1951–1994. Unpublished doctoral dissertation, Stanford University, Stanford, CA.

Taylor, J., M. R. Johnson, C. G. Crawford. 2006. *DVD Demystified*. McGraw-Hill, New York.

Tushman, M. L., P. C. Anderson. 1986. Technological discontinuities and organizational environments. *Admin. Sci. Quart.* **31** 439–465.

Zuckerman, E. 1999. The categorical imperative: Securities analysts and the illegitimacy discount. *Amer. J. Sociol.* **104** 1398–1438.